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Basal Metabolism of Older Women

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BASAL METABOLISM OF OLDER WOMEN

HUGHINA McKAY AND MARY BROWN PATTON

INTRODUCTION

In a previous study from this Station the basal metabolism of 91 young women from 14 to 18 years of age was observed and reported (12). With the young women studied, no relationship between total basal heat production per day and age was shown. The average total heat production of the 14-year-olds was 1340 calories, as compared to an average of 1365 calories for the 18-year-olds. Average heat production per centimeter of height differed little among the age groups studied.

On the other hand, heat production per kilogram of body weight and per square meter of surface area was found to decrease consistently with age. Data for college girls from 17 to 21 reported by Stark (13) "in a general way show an unmistakable downward trend of heat production from younger to older girls".

The effect of age upon the basal metabolism of younger girls has been shown through the studies of Benedict (3), Talbot (14), MacLeod (9), Blunt (4), Lewis (7), Makagawa (10), and others. In general, after the second year of life, basal metabolism decreases consistently per unit as age increases, with perhaps a slight rise during the pre-puberty period, until early adulthood is reached. During the years of early adulthood the basal metabolic rate remains relatively constant, age seemingly playing a very minor part during these years. The changes in heat production during successive years of early adulthood are so small that other factors may easily mask them. Observations in Benedict's laboratory showed remarkably constant heat production of a woman between the ages of 24 and 36 years (1).

Unfortunately, observations of the basal metabolism of the same individual over a period long enough to show changes which may take place in energy production of the body with increasing age are not often feasible. Group figures show little change in heat production during the years of early adulthood.

Although there have been numerous observations of the basal metabolism of children and of young adults, studies on the basal metabolism of older women have been somewhat limited in number. Especially for persons beyond the age of forty there are few data.

A review of the studies on the relation of age to basal metabolism published prior to 1932 has been given by Benedict and Meyer (2). In the same publication the authors also give the results of their observations of basal metabolism of 23 women from 66 to 86 years of age.

In 1934, Kise and Ochi (6) published basal metabolism figures for 50 normal Japanese women between the ages of 54 and 86. More recently Matson and Hitchcock (11) reported basal metabolism figures for eight women from 77 to 106 years of age.

Basal metabolism figures for a group of 73 women, ranging from 35 to 70 years of age are herein reported. All the women who served as subjects were in seemingly good health at the time of the observations and were carrying on their usual activities.

Forty-three of the 73 women were between 35 and 50 years of age. Of these 43 women, 14 were members of the instructional staff of the Ohio State University. Six were graduate students. These 20 women were all engaged in teaching, in research, or in studying and were living sedentary lives. The remaining 23 women of the 35 to 49-year group were homemakers, some of them being wives of professional men. These women were active in various organizations, managing their homes, doing much of the actual house work, and carrying on the usual activities of homemakers of such a group. These homemakers were probably more active physically than the women who were students or teachers.

Of the 73 subjects, 30 were from 50 to 71 years of age. They were from two rather clearly defined groups on the basis of physical activity. One group of 16 subjects which included wives of faculty men, faculty women, and other women on an economic level which precluded need of their doing heavy house work themselves was undoubtedly less active physically than the others in this age group and would be considered as leading sedentary lives. The remaining 14 women were all decidedly active physically. A number were employed in a refectory managed in connection with the School of Home Economics. The others were doing all their house work. The oldest woman in the group was an unusually active, vigorous woman above the average in weight. These 14 women would be considered active rather than sedentary in their occupations, all being engaged in work calling for greater expenditure of energy than the work done by the other women of this age group.

METHOD AND PROCEDURE

Each woman came to the laboratory in the morning before breakfast. She then rested, lying comfortably relaxed for one-half hour or more. During this rest period pulse and respiration rates were counted and temperature was taken by mouth. In any case in which the temperature was above normal, observations were postponed until a time when the temperature was normal.

Observations were begun in 1929 and extended through 1934, being made at such times as subjects could be obtained.

The Benedict-Roth respiration apparatus, an apparatus of the closed circuit type with flutter valves, was used. The machine was tested periodically by a normal control. The procedure followed has been described in a previous report (12).

Each test consisted of two observations of 10 minutes each, between which there was a reasonably close agreement. The lower of the two sets of figures was used since any slight error which might arise would tend to raise rather than lower the basal metabolism.

Tests were repeated on a second and sometimes on a third morning. The figures reported, therefore, represent the average of the lower figures of at least four tests, the results of which were in satisfactory agreement.

Calories of basal heat production were calculated from the oxygen consumption figures, assuming that an individual in the postabsorptive condition has a respiratory quotient of 0.82. For this respiratory quotient it is assumed that the calorie equivalent of oxygen is 4.825 calories per liter.

Heights in stocking feet and nude weights were determined for all the women. Age was taken to that of the nearest birthday. As shown in Figure 1, the members of the group differed considerably one from the other in regard

to body build. The number of cases falling outside the line of regression of weight upon height was 17, or 23 per cent of the entire number. Of these, 10 were above and seven were below the normal zone.

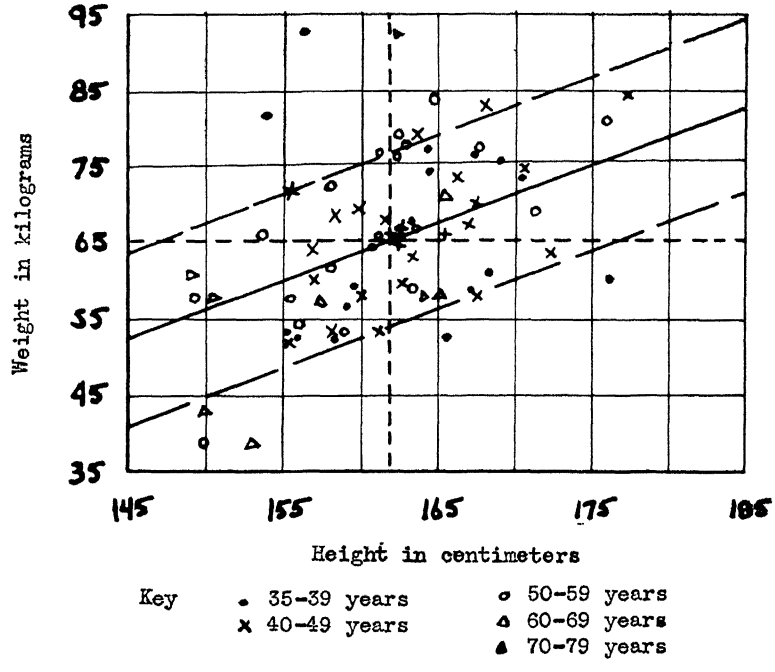

Fig. 1.—Height-weight chart

RESULTS

Table 1 gives the fundamental data concerning the basal heat production of each of the 73 women. In Table 2 the data have been compiled to show the average figures for each age group. These tables show a fairly consistent decrease in average heat production whatever the basis of comparison. Statistical treatment of the data is shown in Table 3.

TOTAL HEAT PRODUCTION

HEAT PRODUCTION AS RELATED TO AGE

For the entire group of 73 women, ranging in age from 35 to 70, the average total daily heat production (computed) was 1326 with a range of from 1025 to 1708 calories. Table 4 shows the range, the median, and the average total heat production for each age group.

Standard deviation, coefficient of variation, and probable error of mean as based on the total calorie intake are shown in Table 3 for each age group. These measures show the variability within each age group.

TABLE 1.—Energy Production of 73 Women 35 Years of Age and Older

Subject	No. of days observations	Age	Weight	Height	Surface area	Average oxygen per min.	Calories				Deviations from standards		
							Per 24 hr.	Per kg. per 24 hr.	Per cm. per 24 hr.	Per sq. m. per hr.	Aub-DuBois	Harris-Benedict	Dreyer
		Yr.	*Kg.*	*Cm.*	*Sq. m.*	*Cc.*					*Pct.*	*Pct.*	*Pct.*
1	2	35	75.3	169.2	1.86	204	1418	18.84	8.40	31.78	−12.95	− 6.78	− 6.18
2	3	35	58.7	167.4	1.67	189	1311	22.33	7.85	32.71	−10.46	− 4.01	− 2.28
3	2	35	61.2	168.4	1.70	180	1250	20.44	7.44	30.74	−15.84	− 9.46	− 7.97
4	2	36	52.4	158.5	1.51	178	1235	23.57	7.82	34.08	− 6.62	− 3.28	− 1.56
5	3	36	81.4	153.9	1.79	217	1509	18.54	9.80	35.12	− 3.73	− 2.42	− 3.59
6	1	36	52.8	165.9	1.58	193	1341	25.40	8.08	35.37	− 3.15	+ 3.10	+ 5.95
7	2	36	53.6	155.7	1.52	182	1259	23.49	8.07	34.52	− 5.48	− 2.12	− 1.13
8	2	36	52.5	161.8	1.55	194	1352	25.74	8.35	36.34	− 0.50	+ 4.49	+ 6.78
9	2	37	77.3	164.6	1.84	220	1534	19.84	9.30	34.72	− 4.92	+ 0.62	+ 0.86
10	3	37	64.6	161.0	1.69	197	1369	21.19	8.50	33.76	− 7.54	− 2.31	− 2.06
11	2	37	56.2	159.3	1.57	190	1316	23.42	8.28	34.93	− 4.29	+ 0.36	+ 1.46
12	2	37	67.8	163.6	1.74	190	1323	19.52	8.07	31.68	−13.19	− 7.82	− 7.42
13	2	38	76.8	167.6	1.87	228	1586	20.66	9.44	35.35	− 3.21	+ 4.00	+ 4.74
14	3	38	52.4	156.2	1.50	177	1231	23.48	7.89	34.18	− 6.43	− 2.52	− 1.17
15	2	38	69.1	164.8	1.76	228	1586	22.96	9.61	37.54	+ 2.93	+ 9.95	+10.50
16	2	38	92.5	156.2	1.92	204	1414	15.28	9.06	30.69	−15.94	−14.60	−15.10
17	2	39	58.9	159.8	1.61	190	1320	22.40	8.24	34.15	− 6.49	− 1.08	− 0.08
18	2	39	61.1	176.3	1.75	206	1434	23.48	8.15	34.15	− 6.48	+ 3.46	+ 6.34
Average for 30 to 39-year age group							1377	21.70	8.46	33.99			
19	2	41	53.6	161.3	1.56	165	1147	21.40	7.12	30.64	−14.96	−10.17	− 8.68
20	2	41	46.9	155.4	1.43	168	1162	24.76	7.50	33.84	− 6.03	− 3.21	− 0.87
21	3	42	67.4	167.1	1.76	200	1393	20.78	8.34	33.10	− 8.02	− 0.47	+ 0.58
22	2	42	57.6	167.4	1.65	206	1427	24.78	8.54	36.03	+ 0.08	+ 7.90	+ 9.91
23	3	43	73.3	166.4	1.81	203	1410	19.23	8.49	32.45	− 9.91	− 3.39	− 2.88
24	2	43	83.2	168.1	1.93	212	1474	17.71	8.77	31.80	−11.67	− 5.56	− 4.79
25	2	43	84.6	177.3	2.02	246	1708	20.18	9.65	35.22	− 2.14	+ 7.06	+ 8.98
26	2	44	63.0	163.3	1.68	190	1322	20.98	8.11	32.80	− 8.94	− 2.67	− 1.90
27	2	44	59.6	157.0	1.60	181	1260	21.13	8.02	32.79	− 8.91	− 4.08	− 3.95
28	2	44	68.4	158.2	1.70	192	1334	19.51	8.44	32.70	− 9.16	− 4.14	− 4.41

TABLE 1.—Energy Production of 73 Women 35 Years of Age and Older—Continued

Subject	No. of days observations	Age	Weight	Height	Surface area	Average oxygen per min.	Calories				Deviations from standards		
							Per 24 hr.	Per kg. per 24 hr.	Per cm. per 24 hr.	Per sq. m. per hr.	Aub-DuBois	Harris-Benedict	Dreyer
		Yr.	*Kg.*	*Cm.*	*Sq. m.*	*Cc.*					*Pct.*	*Pct.*	*Pct.*
29	2	44	74.8	168.2	1.85	198	1371	18.33	8.16	30.88	—14.24	— 7.28	— 6.57
30	2	44	58.0	160.3	1.60	206	1432	24.70	8.94	37.31	+ 3.63	+10.13	+11.10
31	3	44	70.0	167.6	1.79	193	1342	19.16	7.99	31.23	—13.20	— 6.20	— 5.32
32	2	44	65.5	165.6	1.74	187	1298	19.81	7.82	31.07	—13.64	— 6.14	— 5.40
33	2	45	69.4	159.8	1.72	209	1450	20.90	9.08	35.14	— 2.10	+ 3.51	+ 3.49
34	2	46	68.0	162.0	1.73	223	1548	22.76	9.56	37.28	+ 3.04	+11.02	+11.28
35	2	46	64.1	157.0	1.65	202	1403	21.89	8.94	35.44	— 1.58	+ 4.55	+ 4.24
36	2	46	63.8	172.5	1.76	196	1367	21.42	7.95	32.36	—10.16	+ 0.24	+ 1.55
37	2	46	64.3	162.6	1.69	188	1305	20.30	8.00	32.17	—10.58	— 3.60	— 3.08
38	2	46	65.9	161.8	1.70	196	1366	20.74	8.44	33.49	— 6.98	— 0.30	— 0.12
39	2	47	65.8	162.3	1.70	229	1592	24.20	9.82	39.02	+ 8.42	+16.60	+16.75
40	2	47	71.8	155.7	1.72	197	1368	19.06	8.76	33.14	— 7.93	— 2.92	— 3.70
41	2	47	59.3	162.6	1.63	192	1336	22.53	8.20	34.16	— 5.16	+ 2.72	+ 3.65
42	2	48	78.9	163.8	1.86	214	1482	18.79	9.04	33.22	— 7.79	— 0.38	— 0.22
43	2	48	53.9	158.2	1.54	180	1250	23.20	7.92	33.83	— 5.96	+ 0.97	+ 1.64
Average for 40 to 49-year age group							1382	21.13	8.46	33.64			
44	3	50	81.1	176.0	1.97	204	1418	17.48	8.06	29.99	— 14.39	— 6.83	— 5.29
45	2	50	58.9	163.6	1.64	179	1242	21.08	7.57	31.55	— 9.85	— 3.64	— 2.88
46	2	50	64.9	161.3	1.69	171	1186	18.28	7.37	29.26	—16.47	—11.54	—11.52
47	2	50	79.3	162.6	1.85	218	1518	19.14	9.32	34.20	— 5.02	+ 2.69	+ 2.76
48	3	50	73.6	170.7	1.86	188	1303	17.71	7.62	29.19	—16.60	— 9.96	— 9.01
49	2	50	69.2	168.9	1.79	200	1393	20.13	8.24	32.42	— 9.86	— 0.09	+ 0.77
50	2	52	76.4	161.3	1.80	172	1199	15.70	7.45	27.75	—20.72	—16.61	—16.97
51	2	52	77.1	162.8	1.83	212	1472	19.10	9.03	33.52	— 4.40	+ 1.88	+ 1.62
52	2	53	77.3	167.6	1.87	192	1332	17.24	7.93	29.68	—15.25	— 8.49	— 8.02
53	3	54	57.9	147.1	1.50	171	1190	20.55	8.09	33.04	— 5.59		— 5.28

TABLE 1.—Energy Production of 73 Women 35 Years of Age and Older—Concluded

Subject	No. of days observations	Age	Weight	Height	Surface area	Average oxygen per min.	Calories				Deviations from standards		
							Per 24 hr.	Per kg. per 24 hr.	Per cm. per 24 hr.	Per sq. m. per hr.	Aub-DuBois	Harris-Benedict	Dreyer
		Yr.	*Kg.*	*Cm.*	*Sq. m.*	*Cc.*					*Pct.*	*Pct.*	*Pct.*
54	2	54	66.7	163.6	1.73	164	1140	17.08	6.96	27.45	−21.63	−15.35	−15.52
55	3	55	57.7	155.4	1.56	210	1455	25.28	9.39	38.96	+11.32	+17.79	+16.44
56	2	55	65.5	153.7	1.63	158	1101	16.81	7.16	28.14	−19.66	−15.67	−16.85
57	2	56	53.2	159.0	1.53	174	1210	22.76	7.62	32.97	− 5.89	+ 1.30	+ 1.26
58	2	56	83.7	165.1	1.91	205	1424	17.02	8.62	31.08	−11.28	− 5.19	− 5.28
59	2	56	61.7	158.0	1.63	168	1166	18.90	7.38	29.81	−14.92	− 8.84	− 9.66
60	3	57	72.2	158.0	1.74	208	1448	20.05	9.16	34.67	− 0.93	+ 5.66	+ 4.38
61	3	57	38.4	150.1	1.28	151	1051	27.36	7.00	34.20	− 2.29	+ 2.52	+ 4.37
62	2	59	76.3	162.6	1.82	200	1394	18.27	8.58	31.92	− 8.81	− 1.02	− 1.84
Average for 50 to 59-year age group							1297	19 47	8.03	31.57			
63	3	60	54.3	156.2	1.52	180	1254	23.09	8.03	34.37	+ 1.05	+ 6.40	+ 4.96
64	3	60	71.0	165.6	1.79	192	1338	18.85	8.08	31.15	− 8.45	− 1.66	− 2.28
65	2	60	60.5	149.1	1.54	163	1132	18.72	7.60	30.64	− 9.95		−10.07
66	2	61	57.2	150.4	1.52	148	1039	18.16	6.90	28.48	−16.28	−12.94	−15.14
67	2	63	65.4	162.0	1.69	166	1148	17.56	7.08	28.28	−16.79	−10.40	−11.76
68	2	64	38.9	153.2	1.31	148	1028	26.42	6.71	32.69	− 3.76	+ 1.72	+ 2.12
69	3	65	57.8	157.7	1.58	147	1025	17.73	6.50	27.02	−20.49	−14.44	−16.33
70	2	66	58.4	165.1	1.64	176	1150	19.68	6.97	29.20	−14.18	− 4.64	− 5.95
71	2	68	57.9	164.3	1.63	156	1086	18.76	6.62	27.76	−18.32	− 9.14	−10.77
72	3	69	43.3	149.9	1.34	156	1082	24.99	7.22	33.32	− 1.12	+ 5.85	+ 3.51
Average for 60 to 69-year age group							1128	20.40	7.17	30.29			
73	2	70	92.1	16.2	1.96	223	1552	16.85	9.56	32.98	− 0.09	+ 2.93	+ 1.59

TABLE 2.—Average Calorie Production of 73 Women 35 Years of Age and Older

Age	Number of subjects	Average heat production in calories			
		Per 24 hr.	Per kg. per 24 hr.	Per cm. per 24 hr.	Per sq. m. per hr.
Yr.					
35–39	18	1377	21.70	8.46	33.99
40–49	25	1382	21.13	8.46	33.64
50–59	19	1297	19.47	8.03	31.57
60–69	10	1128	20.40	7.17	30.29
70–79	1	1552	16.85	9.56	32.98
Average	73	1326	20.70	8.20	32.60

TABLE 3.—Measure of Variability Within Each Age Group

Age	Mean and standard deviation	Coefficient of variation	Probable error of mean	Probable error of mean Per cent
Calories per 24 hours				
35–39	1377±118.90	7.91	17.32	1.26
40–49	1382±121.03	8.76	16.33	1.18
50–59	1297±138.15	10.65	21.37	1.65
60–69	1128± 96.58	8.56	20.61	1.83
Calories per kilogram per 24 hours				
35–39	21.70± 2.57	11.84	0.409	1.88
40–49	21.13± 2.01	9.51	0.271	1.28
50–59	19.47± 2.90	14.89	0.449	2.31
60–69	20.40± 3.05	14.95	0.651	3.19
Calories per centimeter per 24 hours				
35–39	8.46± 0.664	7.85	0.106	1.25
40–49	8.46± 0.646	7.64	0.087	1.03
50–59	8.03± 0.768	9.56	0.119	1.48
60–69	7.17± 0.533	7.43	0.114	1.59
Calories per square meter per hour				
35–39	33.99± 1.80	5.30	0.286	0.84
40–49	33.64± 2.10	6.24	0.283	0.84
50–59	31.57± 2.82	8.93	0.436	1.38
60–69	30.29± 2.41	7.96	0.514	1.70

TABLE 4.—Average Total Heat Production, Median, and Range of a Group of 72 Women

Age group	Number of cases	Average total calories	Median	Range
35–39	18	1377	1346.5	1231–1586
40–49	25	1382	1368.0	1147–1708
50–59	19	1297	1303.0	1051–1518
60–69	10	1128	1109.0	1025–1338
35–69	72	1323	1335.0	1025–1708

Standard deviation was least for the 60 to 69- and greatest for the 50 to 59-year group. The chances are two to one that the total heat production of all women between 60 and 69 years of age lies between 1128 ± 97 calories, or between 1031 and 1224 calories. In contrast to these figures, the true mean for the 50 to 59-year group would be 1297 ± 138, or between 1159 and 1435 calories.

Because the values of the standard deviations of the two groups are not directly comparable unless they are measured around the same central tendency, it was necessary to calculate the coefficient of variation in order to compare the variability among the four age groups. This figure shows the 35 to 39-year group to be the least and the 50 to 59-year group to be the most variable.

Probable error of the mean (an estimate of the variation that might be expected in the mean if additional samples were to be taken) shows that the data for the two younger groups are more reliable than those for the two older groups.

As shown by the figures in Table 2 there was very little difference between the total average calorie production of the women 35 to 39 and those from 40 to 49 years of age. One of the women in the 40 to 49 group had the unusually high basal metabolism of 1708 calories per 24 hours. Omission of this figure in compiling the average of the 40 to 49-year group gave an average which was only slightly below that of the younger group. The age factor, therefore, seemed to have little or no influence on total heat production with the women of these two age groups. A similar conclusion may be drawn from Benedict's figures (see Table 5).

The average total heat production of the two older groups (50 to 59 and 60 to 69) was each lower than that of the preceding group, the percentage difference being 6 and 15, respectively. Comparison of the youngest group (35 to 39) with the oldest group (60 to 69) showed that the latter group averaged 249, or 22 per cent, fewer total calories than the former group. The effect of age on the total calorie production of the 72 women from 35 to 69 years of age seems quite evident but does not seem apparent until after the age of 50 is reached.

Comparison with the results from the several studies referred to previously is shown in Table 5. As shown by this table greatest differences among results appear in the 50 to 59-year age group.

TABLE 5.—Daily Calorie Production of Older Women as Shown by Available Studies

Studies	Age groups					
	35–39	40–49	50–59	60–69	70–79	80–89
Benedict	1387‡	1368‡	1445‡	1145*	1148*	1011*
Kise and Ochi	.....	.....	1059†	999†	.....	.....
Hitchcock	.....	.....	.....	.....	.....	1048§
This study	1377	1382	1297	1128	.....	.....

*Amer. Phil. Soc. 71 (1932): 143.
†Jour. Lab. and Clin Med. 19 (1934): 1073.
‡Jour. Physiol 85 (1928): 612.
§Amer. Jour. Physiol. 110 (1934): 329.

Values for Student's t were computed to show the possibility of significant relationships between the average total heat production of one age group as compared to that of another. As shown by these values, no significance could

be attached to the factor of age when the 35 to 39-year group was compared to the 40 to 49-year group nor when the latter group was compared to the 50 to 59-year group. A Student's t of 3.45 indicated that age was significant when the 50 to 59-year group was compared to the 60 to 69-year group. When the women were divided into two groups, one 35 to 49 and the other 50 to 69, a Student's t of 4.388 gives further evidence of the effect of age in slowing up the energy production of women and some indication of when the decrease may be expected.

Figure 2 shows the average calorie production for each age group, as well as for each individual, and shows the decrease with increasing years.

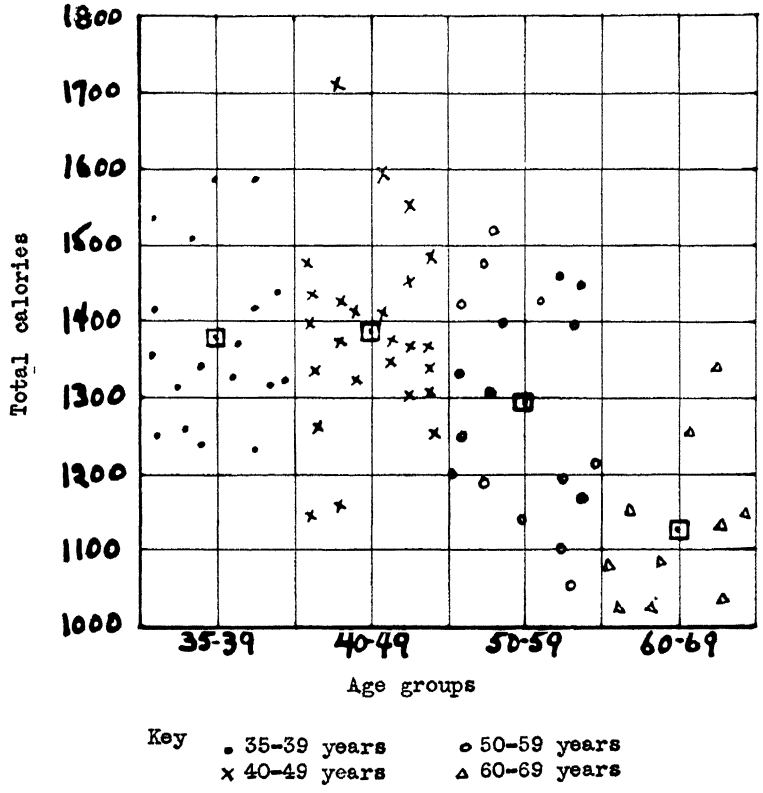

Fig. 2.—Total heat production of women 35 to 70 years of age

In this study there was an opportunity to compare total heat production of those women who had passed the menopause with those who had not yet reached that period. Table 6 shows that average calorie production of the latter group averaged 10 per cent more than that of the former. With very few exceptions those under 50 were in the premenopause and those over 50 in the postmenopause period. To separate the effect of age from that of the menopause is of course impossible in such a study.

TABLE 6.—Comparison of the Average Heat Production of Women in the Premenopause Period with Those in the Postmenopause Period

	Number of cases	Total calories	Calories per kg.	Calories per sq. m.
Premenopause	41	1379	21.45	33.81
Postmenopause	32	1258	19.69	31.33

Average basal metabolism figures were approximately the same for the women engaged in sedentary occupations as for those who were more active physically.

HEAT PRODUCTION AS RELATED TO WEIGHT

With the group of women studied, age was not the only factor influencing basal metabolism. Weight, height, and surface area are also to be considered.

The weight of the individual women varied greatly, ranging from 38.4 to 92.5 kilograms. Figure 1, showing the regression of weight on height, indicates what might be considered a zone of normal weight for these women and shows the number above as well as below the zone. The ten women in the zone above the normal might be considered overweight and the seven women below the zone underweight.

The 56 women in the normal zone averaged a total heat production of 1321 calories, as compared to an average of 1207 calories for the seven individuals who were underweight and an average of 1441 calories for the 10 who were overweight. Underweights and overweights each deviated from the normal by approximately 19 per cent (Table 7).

TABLE 7.—Average Heat Production of Women of Normal, Below Normal, and Above Normal Weight

	No. of cases	Total calories	Average heat production		
			Per kg. per 24 hr.	Per cm. per 24 hr.	Per sq. m. per hr.
Below	7	1207	25.45	7.57	34.27
Normal	56	1321	20.16	8.13	32.59
Above	10	1441	17.72	8.94	32.35
Total	73	1326	20.68	8.19	32.72

Similar results were shown when the women were grouped according to weight, disregarding age (Table 8). With the exception of the last group, for which there are only two cases, total heat production increased consistently with increased weight.

Heat production per centimeter also increased consistently as weight increased, with heat production per kilogram as consistently decreasing with increased weight. Calorie production per square meter remained fairly constant regardless of weight.

TABLE 8.—Average Heat Production Referred to Weight

Weight in kg.	No. of cases	Total calories	Average heat production		
			Per kg. per 24 hr.	Per cm. per 24 hr.	Per sq. m. per hr.
30–39	2	1040	26.89	6.86	33.44
40–49	2	1122	24.88	7.36	33.58
50–59	23	1255	22.38	7.87	33.23
60–69	23	1331	20.36	8.18	32.54
70–79	16	1407	18.75	8.55	32.18
80–89	5	1507	18.19	8.98	32.64
90–99	2	1483	16.06	9.31	31.84

HEAT PRODUCTION AS RELATED TO HEIGHT

The height of the women studied ranged from 147.1 to 177.3 centimeters, with the largest number of the women between 160 and 169 centimeters in height. Table 9 shows that total calorie production increased consistently as height increased. Calories per kilogram decreased as height increased. Calories per square meter remained practically the same regardless of height.

TABLE 9.—Average Heat Production Referred to Height

Height	No. of cases	Total calories	Average heat production		
			Per kg. per 24 hr.	Per cm. per 24 hr.	Per sq. m. per hr.
Cm.					
140–149	3	1135	21.42	7.64	32.33
150–159	24	1262	21.55	8.07	33.16
160–169	41	1363	20.19	8.29	32.56
170–179	5	1446	20.05	8.29	32.18

HEAT PRODUCTION AS RELATED TO SURFACE AREA

Total calories and calories per centimeter increased with increasing surface area. Calories per kilogram and calories per square meter decreased with surface area (Table 10).

TABLE 10.—Average Heat Production Referred to Surface Area

Surface area	No. of cases	Total calories	Average heat production		
			Per kg. per 24 hr.	Per cm. per 24 hr.	Per sq. m. per hr.
Sq. m.					
1.20–1.29	1	1051	27.36	7.00	34.20
1.30–1.39	2	1055	25.70	6.96	33.00
1.40–1.49	1	1162	24.76	7.50	33.84
1.50–1.59	15	1229	22.40	7.84	33.29
1.60–1.69	18	1267	20.76	7.83	32.00
1.70–1.79	18	1402	20.50	8.57	33.48
1.80–1.89	12	1418	18.57	8.56	32.06
1.90–1.99	5	1456	16.87	8.81	31.31
2.00–2.09	1	1708	20.18	9.65	35.22

These figures all tend to show how difficult it is to separate the effects of physical development, as indicated by weight, height, and surface area of the individual, from the effects of age.

HEAT PRODUCTION PER KILOGRAM AND PER SQUARE METER REFERRED TO AGE

The weights of the women varied greatly. Energy production per kilogram was therefore computed and the average for each age group determined (Table 1).

The same statistical measures as were used for total calories were calculated for calorie production per kilogram for each age group (see Table 3). The values indicate that there was a greater variation among the members of the 60 to 69-year group than among any of the other groups studied.

On the basis of calorie production per kilogram, very little difference was found between the average heat production of the two younger groups (35 to 39 and 40 to 49). This was also the case when the two older groups (50 to 59 and 60 to 69) were compared one to the other. However, when the youngest group (35 to 39) was compared to the oldest group (60 to 69), a difference of 6 per cent gives some evidence that, on the basis of heat production per kilogram, age exerts an influence. Benedict (2) found "no regularity in the heat production per unit of body weight as associated with age" but did find that "even at the same body weights, elderly women have a definitely lower metabolism per unit of weight than do younger women".

Using height and weight figures, surface area was assumed for each of the women by use of the Du Bois body surface chart. Surface areas ranged from 1.28 to 2.02 square meters. Energy production per square meter per hour is shown for each of the women in Table 1, and average figures for each age group in Table 2.

Differences in calorie production per square meter per hour between the 35 to 39- and the 40 to 49-year groups were so slight as to be negligible. This was also the case when the two older groups were compared one to the other. Comparison of the average heat production per square meter of the two younger groups (35 to 49) and the two older groups (50 to 69) shows a decrease of 9 per cent which may be assumed as being due to age. A Student's t of 4.65 when the 35 to 49-year group was compared to the 50 to 69-year group showed the difference in age to be significant. With a group of 32 women ranging in age from 66 to 86 years, Benedict (2) says: "The general tendency therefore is for lower heat production per square meter of surface area with advancing age."

SUMMARY AND CONCLUSIONS

Basal metabolism figures for 73 women ranging from 35 to 71 years of age have been determined. Average basal heat production figures for each of the age groups (35 to 39, 40 to 49, 50 to 59, 60 to 69) are presented, as well as individual figures for each of the subjects.

Average heat production, whether expressed as total calories, calories per kilogram, calories per centimeter per 24 hours, or calories per square meter per hour, was practically the same for the two younger groups (35 to 39 and 40 to 49). Evidently, the age factor was insignificant in its effect on heat production during these ages for this group of women.

The two older groups (50 to 59 and 60 to 69) showed a decrease in heat production on the basis of total calories, calories per centimeter, and calories per kilogram per 24 hours, as well as on the basis of calories per square meter per hour.

These findings justify the conclusion that basal metabolism of women remains at a fairly uniform level until the age of 50 or thereabouts is reached, after which the heat production declines to a definitely lower level.

LITERATURE CITED

1. Benedict, F. G. 1928. Age and basal metabolism of adults. Amer. Jour. Physiol. 85: 650.
2. ———— and M. H. Meyer. 1932. The basal heat production of elderly women. Proc. Amer. Phil. Soc. 71: 143.
3. ———— and F. Talbot. 1921. Metabolism and growth from birth to puberty. Carnegie Inst. of Washington Pub. 302.
4. Blunt, K., J. Tilt, L. McLaughlin, and K. Gunn. 1926. Basal metabolism of girls. Jour. Biol. Chem. 67: 491.
5. Du Bois, E. 1924. Body surface (in sq. m.) calculated from Du Bois' height-weight formula. P. B. Hoeber, Inc., New York, N. Y.
6. Kise, Y. and T. Ochi. 1934. Basal metabolism of old people. Jour. Lab. and Clin. Med. 19: 1073.
7. Lewis, C. A. 1936. Relation between basal metabolism and adolescent growth. Amer. Jour. Dis. Child. 51: 1014.
8. Lucas, W. P. and H. B. Pryor. 1933. The body build factor in the basal metabolism of children. Amer. Jour. Dis. Child. 46: 941.
9. MacLeod, G. 1924. Studies of the normal basal energy requirements. Dissertation, Columbia University, New York.
10. Makagawa, I. 1934. Growth and basal metabolism. Amer. Jour. Dis. Child. 47: 963.
11. Matson, J. R. and F. A. Hitchcock. 1934. Basal metabolism in old age. Amer. Jour. Physiol. 110: 329.
12. McKay, H. 1930. Basal metabolism of young women. Ohio Agr. Exp. Sta. Bull. 465.
13. Stark, M. E. 1933. Standards for predicting basal metabolism. Jour. Nutr. 6: 11.
14. Talbot, F. B. 1921. Standards of basal metabolism in normal infants and children. Amer. Jour. Dis. Child. 25: 519.